TOPEX/PO SEIDON Orbit Determination Using Global Positioning Satellites in Anti-Spoofing Mode

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ABSTRACT

Results of operational orbit determination for the TOPEX/Poseidon ('171') mission using Global Positioning Satellites (GPS) during Anti-Spoofing (AS) activities are presented in this paper. Sub-decimeter radial orbit comparisons have been made with solutions determined from LASER and DORIS tracking.

During AS tracking the T/P GPS flight receiver tracks only the L_1 carrier and CA-code pseudorange. '1'bus, the ionosphere calibration based cm the linear combination of the L_1 and L_2 carrier signals is unavailable. An approximation of the ionosphere above T/P can be obtained by differencing the available carrier phase. and pseudorange measurements. This difference is smoothed to remove. the multipath associated with the pseudorange measurements. The remaining signal consists primarily of ionosphere. The following mathematical description shows the procedure:

1) Form $A = L_1 - P_1 = \rho + I + B_L - (\rho - I + M + B_P) = 2I - M + B_L - B_P$

Where:
- L_1 = (;A-code carrier phase
- P_1 = CA-code pseudorange
- p = True Range
- I = Ionosphere
- M = Multipath
- B_L = CA-code carrier phase bias
- B_P = CA-code pseudorange bias

2) Smooth A with cubic splints to remove mult ipath; S(A) ≈ 2I -I 11,-111,

3) Apply remaining ionosphere calibration to L_1 and 1',

$L_{1C} = L_1 - S(A)\ /2.$

P_{1C} = (1.] +P_1) / ? and carrier added smoothing

The bias parameters are easily absorbed in the orbit determination process. Also the pseudorange is produced by performing carrier added smoothing (Ref. 1).

For the ground GPS receivers, a CA-code only ionosphere calibration is produced by performing cross-channel correlation. This calibration is performed in the hardware and the only modifications to the orbit determination processing are to modify the effective antenna phase center locations.

Elements of T/P GPS orbit determination include the GPS satellite constellation, GPS flight receiver on-board T/P, six globally distributed GPS ground receivers, the GPS Data Handling Facility (GDHF) and the GPS Data Processing Facility (GDPF). The GDPF collects the GPS flight measurements from the T/P flight operations team while the ground station data is obtained through the GDHF. Carrier phase and P-code pseudorange measurements from 22 GPS satellites to the seven GPS receivers are then processed simultaneously with the GDPF software MIRAGE to produce orbit solutions of T/P and the GPS satellites.

Baseline Solution Scenario

During normal non-AS tracking the L_1 and L_2 carrier signals are modulated with the P-code. in addition, the 1.1 carrier is also modulated with the CA-code. For AS tracking the P-code is replaced by the Y-code (encrypted security cede) which makes it impossible for unclassified users to track the L_2 carrier. The 1.1 carrier is always available since it is modulated with the ~A-code. During AS, some GPS satellites continue to transmit the normal CA-code and P-code signals. The Block I satellites do not have AS capabilities and on occasion some of the BLOCK 11 satellites have not activated AS.

Carrier phase and P-code pseudo range data are available cm the flight receiver at rates of l/see and 10/see respectively. Pre-processing of the observations consists of detecting and correcting cycle slips, determining and applying TOPEX/Poseidon clock offsets, and decimating to the desired processing rate and calibrating for ionosphere. Since the noise level is different for CA-code and P-code measurements the data weights are chosen to balance this effect in the orbit determination process. Table 1. shows the data rates and weights used for operational orbit determination.

Table 1 - Data Rates and Processing Weights

Data Type	Processing Rate	Weight
T/P P-code Carrier Phase	5 min. (decimated)	2 cm
T/P ~A-code Carrier Phase	5 min. (decimated)	15 cm
T/P P-code Pseudo Range	5 min. (decimated)	2 meters
T/P CA-code Pseudo Range	5 min. (decimated)	500" meters
Ground P-code Carrier Phase	S min. (decimated)	1 cm
Ground ~A-code Carrier Phase	5 min. (decimated)	3 cm
Ground P-code Pseudo Range	5 min. (decimated)	1 mete.rs
Ground CA-code Pseudo Range	5 min. (decimated)	50 meters

Results

Orbit comparisons with solutions from LASER and DORIS tracking show RMS radial agreement at the sub-decimeter level. Figure 1. shows the GPS carrier phase residual errors between the actual observations and the computed values. Figure 2. presents radial, transverse and normal orbit comparisons with the official T/P medium precision orbit ephemeris.

Acknowledgements

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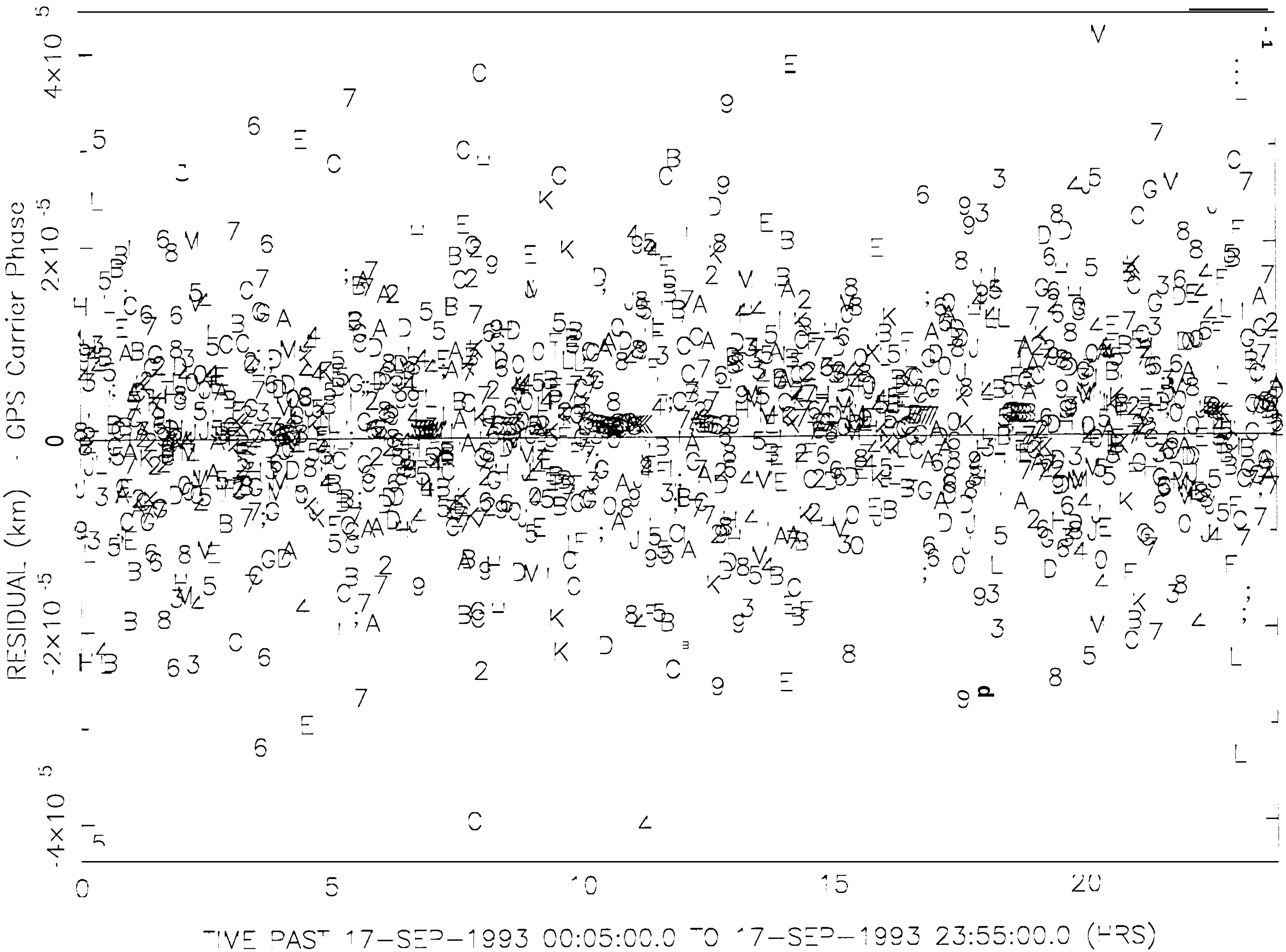
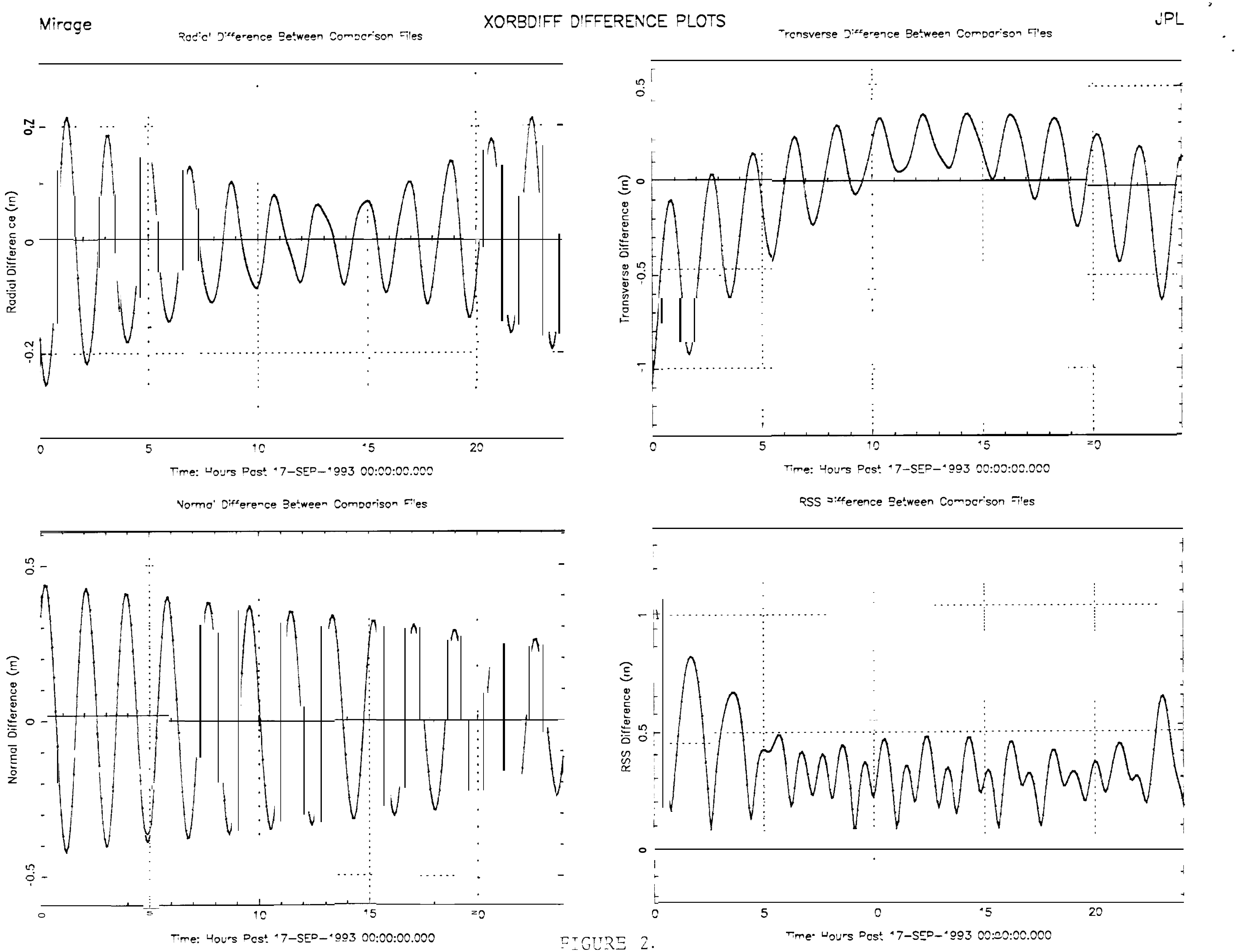
References

1) Wu, S.C., and others, "Minimizing Selective Availability Error on TOPEX GPS Measurements," AIAA-90-2942, AIAA/AAS Astrodynamics Conference, Portland, OR., August, 1990

FIGURE 1.

GPS CARRIER PHASE RESIDUALS (5 minute rate)





Mirage
XORBDIFF DIFFERENCE PLOTS
JPL
Radial Difference Between Comparison Files
Radial Difference (m)
0.2
0
-0.2
0
5
10
15
20
Time: Hours Past 17-SEP-1993 00:00:00.000
Transverse Difference Between Comparison Files
Transverse Difference (m)
0.5
0
-0.5
-1
Time: Hours Past 17-SEP-1993 00:00:00.000
Normal Difference Between Comparison Files
Normal Difference (m)
0.5
0
-0.5
Time: Hours Past 17-SEP-1993 00:00:00.000
RSS Difference Between Comparison Files
RSS Difference (m)
1
0.5
0
Time: Hours Past 17-SEP-1993 00:00:00.000

FIGURE 2.